Purdue University Department of Physics

Physics 22000

General Physics

Mostly mechanics, some fluid mechanics, wave motion and thermodynamics!

Fall 2016 Semester

Prof. Matthew Jones

Physics 22000 – General Physics

- Physics Department home page:
  - http://www.physics.purdue.edu
- Course home page(s):
  - http://www.physics.purdue.edu/~mjones/phys22000_Fall2016
  - http://www.physics.purdue.edu/phys220
- Blackboard Learn:
  - http://mycourses.purdue.edu/
- Mastering Physics:
  - http://www.pearsonmylabandmastering.com/northamerica/
  - Course ID: **physics51079 (I think)**
- Rooms:
  - Physics 114: Lecture theater
  - Physics 121: Lab
  - Physics 144: Undergraduate Office
  - Physics 11: Help center

EMERGENCY PREPAREDNESS – A MESSAGE FROM PURDUE

To report an emergency, call 911. To obtain updates regarding an ongoing emergency, sign up for Purdue Alert text messages, view www.purdue.edu/ea.

There are nearly 300 Emergency Telephones outdoors across campus and in parking garages that connect directly to the PUPD. If you feel threatened or need help, push the button and you will be connected immediately.

If we hear a fire alarm during class we will immediately suspend class, evacuate the building, and proceed outdoors. Do not use the elevator.

If we are notified during class of a Shelter in Place requirement for a tornado warning, we will suspend class and shelter in [the basement].

If we are notified during class of a Shelter in Place requirement for a hazardous materials release, or a civil disturbance, including a shooting or other use of weapons, we will suspend class and shelter in the classroom, shutting the door and turning off the lights.

Please review the Emergency Preparedness website for additional information.
http://www.purdue.edu/ehps/emergency_preparedness/index.html

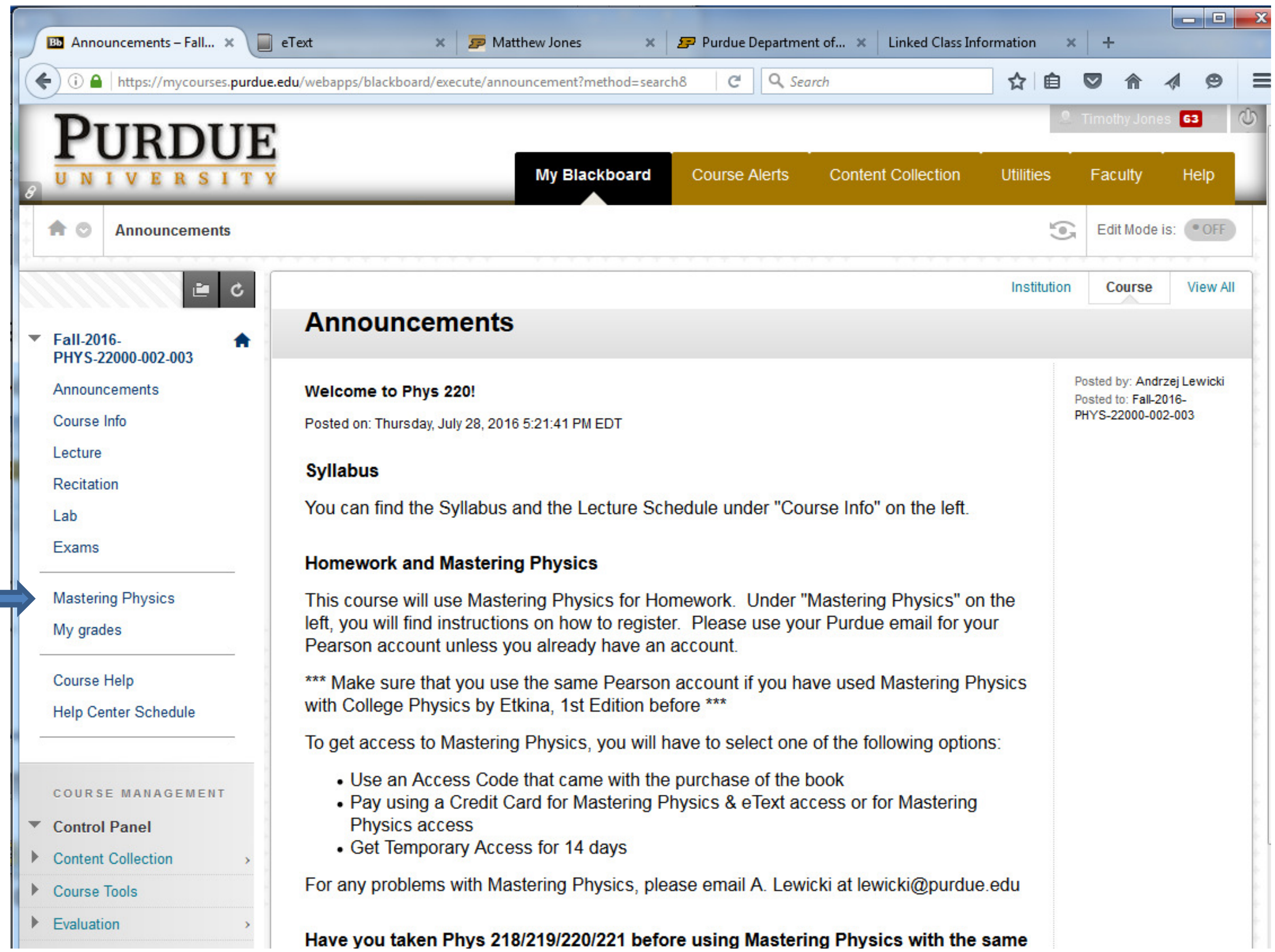
About the Course

- The syllabus is available from one of the web sites listed on the second slide.
  - Describes the grading scheme
  - Course schedule
  - Exam dates
- Assignments will be completed online using Pearson Publishing's MasteringPhysics®…
  - This is an improvement over free alternatives
  - Unfortunately you have to pay for it
  - But you can also use this text for General Physics II.

Online Assignments

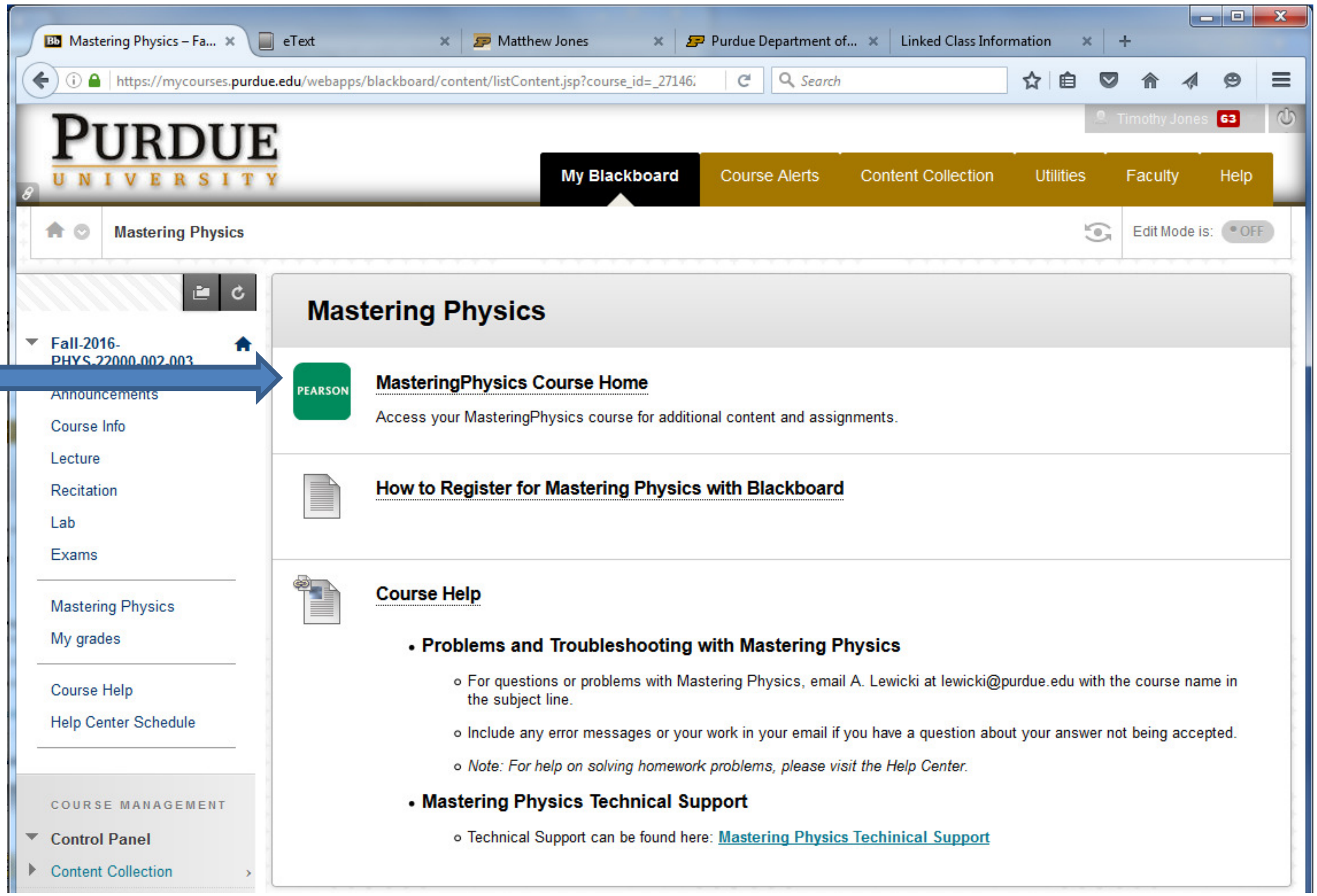
- Somehow get to the course page in Blackboard:

Click on this link



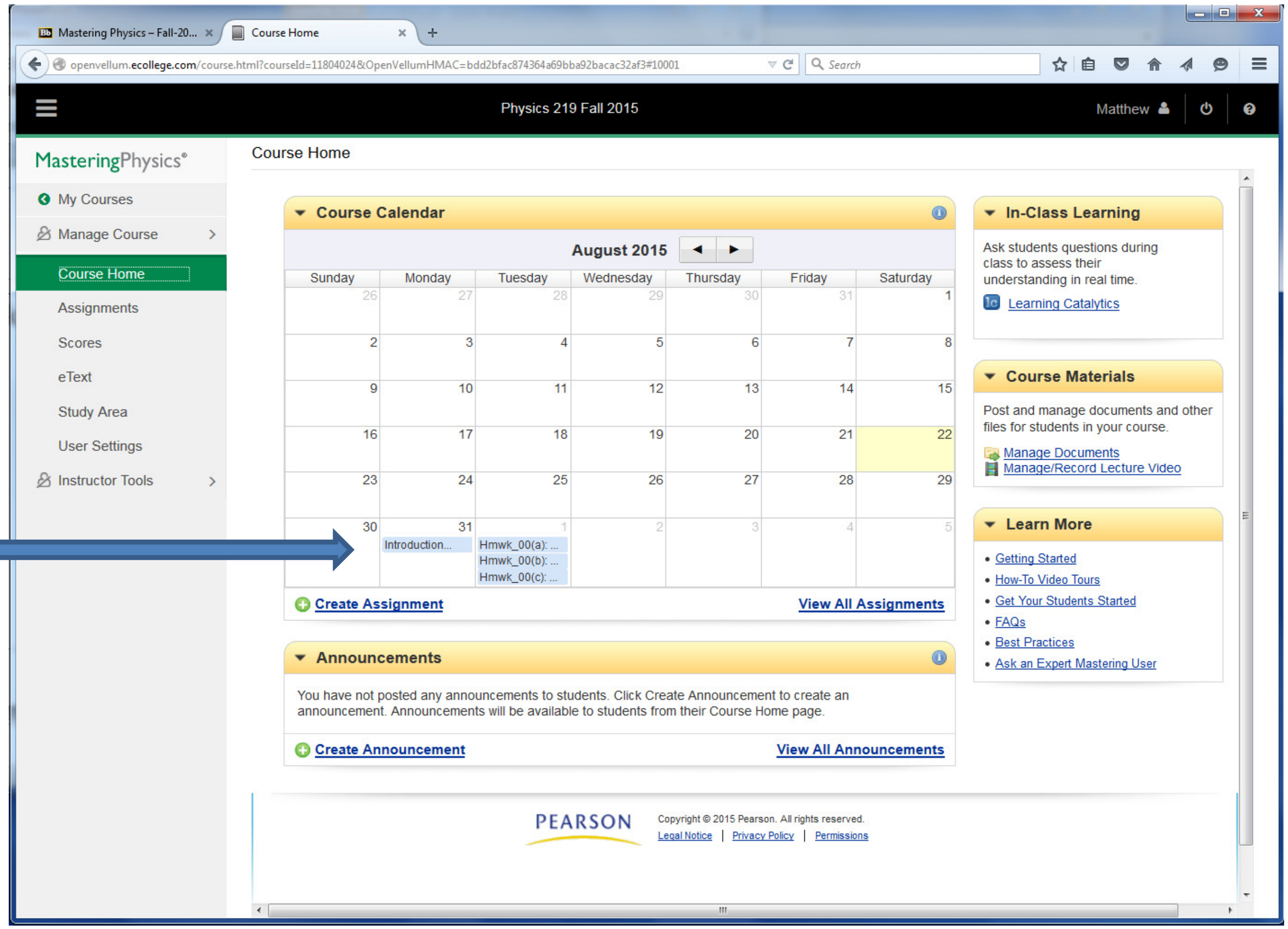
Online Assignments

Now click this link…



MasteringPhysics®

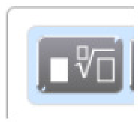
Assignments!



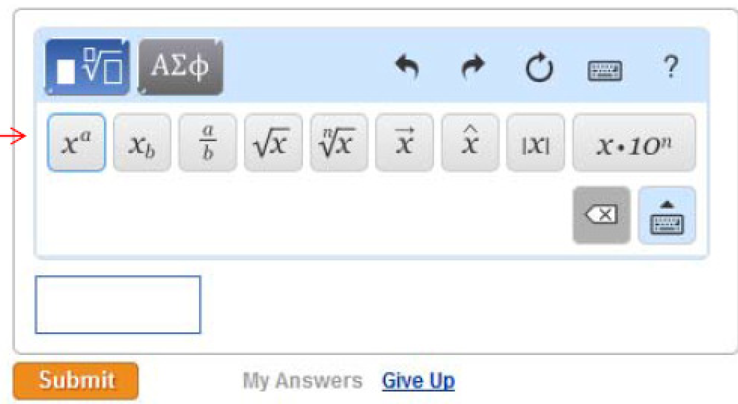
Entering Numerical or Algebraic Answers

If the answer to a question requires a NUMERICAL or ALGEBRIC answer, then the box shown below will appear after a question is posed.

"answer box"

If you click the icon  , then another window will open that looks like:

By clicking on the grey-colored symbols, you can create an equation-like expression in the "answer box" to facilitate any numerical or algebraic answer that you care to enter.



Entering Numerical or Algebraic Answers

For instance, clicking on the $x \cdot 10^n$ icon, causes

the "answer box" to look like this:

You can now enter numbers for the base and power into the "answer box" by positioning the mouse cursor at the end of either of the two red arrows and right clicking the mouse.

Entering Numerical or Algebraic Answers

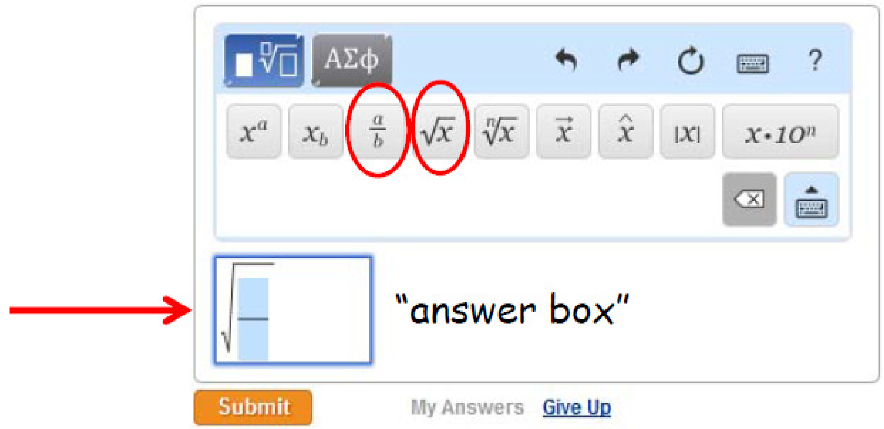
Be aware that Mastering Physics accepts algebraic answers. So, for instance, you can be asked a question like:

If $y=2x^2 + b$, what is x?

The correct answer would be $x = \sqrt{\frac{y-b}{2}}$

Note that Mastering Physics would also accept $x = \sqrt{\frac{-(b-y)}{2}}$

To enter this answer, you would first be required to select the square root symbol (√x) and then the fractional symbol (a/b) by clicking on the options provided in the grey boxes shown below. Then you would type y-b in the numerator blue box and 2 in the denominator blue box. You submit your answer by clicking on the "Submit" orange box.



More Information

- To register for course, go to

http://www.pearsonmylabandmastering.com

when asked, use the Course ID: **physics51079 (I think)**

- To sign into the course to access homework assignments, quizzes, etc., go to

http://www.pearsonmylabandmastering.com/northamerica/

- For a step-by-step guide to get started, go to

http://www.pearsonmylabandmastering.com/northamerica/students/mm-support/index.html

- For a summary of the many features available in Mastering Physics, go to

http://www.pearsonmylabandmastering.com/northamerica/students/features/index.html

- For Questions and Answers about Mastering Physics, go to

http://www.pearsonmylabandmastering.com/northamerica/students/mm-support/top-questions/index.html

- For a Student User Guide, go to

http://help.pearsoncmg.com/mastering/student/ccng/index.htm

SUPPLEMENTAL INSTRUCTION

Free Study Sessions!

Rachel Hoagburg

Come to SI for more help in **PHYS 220**

Tuesday and Thursday	7:30-8:30PM Shreve C113

Office Hour

Tuesday 1:30-2:30 4th floor of Krach

For other SI-linked courses and schedules, visit purdue.edu/si or purdue.edu/boilerguide

And now…

Physics 22000
General Physics

Historical Perspective

- Aristotle was (perhaps) the first to think about the causes of natural phenomena, rather than just document them.
- Most of the physics we will study was developed between 200-400 years ago.
- It provided a quantitative description of nature with accurate predictions.
- Coincident with new developments in mathematics (*eg*. Calculus) that were needed to accurately describe dynamic physical systems.

Mathematical Description of Nature

- In this course, we will try very hard not to mention calculus.
- We will describe many specific examples of physical systems, but usually not try to provide the "most general" description.
- It will be very efficient to describe the properties of physical systems using algebraic equations, but this is just for convenience…
- We will also use graphs, diagrams, tables, and words…

Mathematical Description of Nature

MAY we not infer from this experiment, that the attraction of electricity is ſubject to the ſame laws with that of gravitation, and is therefore according to the ſquares of the diſtances; ſince it is eaſily demonſtrated, that were the earth in the form of a ſhell, a body in the inſide of it would not be attracted to one ſide more than another?

(Joseph Priestly, 1767)

$$F \propto \frac{1}{r^2}$$

Quantitative Description of Nature

- We can work out equations that can describe measurements, in some cases with great accuracy.

$$F = k\frac{Q_1 Q_2}{r^2}$$

- If we had numbers for everything on the right, then we could calculate the thing on the left.
- To use this, we need to agree on a consistent system of units.

System of Units

QUANTITY AND DEFINITION	METRIC cgs	METRIC MKS	ENGLISH FPS
TIME	SECOND	SECOND	SECOND
LENGTH	CENTIMETER	METER	FOOT
MASS	GRAM	KILOGRAM	slug
VELOCITY $v = d/t$	$\frac{\text{centimeter}}{\text{second}}$	$\frac{\text{meter}}{\text{second}}$	$\frac{\text{foot}}{\text{second}}$
ACCELERATION $a = v/t$	$\frac{\text{centimeter}}{\text{second}^2}$	$\frac{\text{meter}}{\text{second}^2}$	$\frac{\text{foot}}{\text{second}^2}$
FORCE $F = ma$	$\frac{\text{gm}\cdot\text{cm}}{\text{sec}^2} \equiv \text{dyne}$	$\frac{\text{kg}\cdot\text{meter}}{\text{sec}^2} \equiv \text{newton}$	POUND
ENERGY (& WORK) $W = fd$	$\frac{\text{gm}\cdot\text{cm}^2}{\text{sec}^2} \equiv \text{erg}$	$\frac{\text{kg}\cdot\text{meter}^2}{\text{sec}^2} \equiv \text{joule}$	foot·pound
POWER $P = W/t$	$\frac{\text{erg}}{\text{sec}}$	$\frac{\text{joule}}{\text{sec}} \equiv \text{watt}$	$\frac{\text{foot}\cdot\text{pound}}{\text{second}}$
MOMENTUM $p = mv$	$\frac{\text{gm}\cdot\text{cm}}{\text{sec}} = \text{dyne}\cdot\text{s}$	$\frac{\text{kg}\cdot\text{meter}}{\text{sec}} = \text{N}\cdot\text{s}$	$\frac{\text{slug}\cdot\text{foot}}{\text{sec}}$
TORQUE $G = F\tau$	dyne·cm	newton·meter	pound·foot
FREQUENCY	$\frac{1}{\text{sec}} = \text{hertz}$	$\frac{1}{\text{sec}} = \text{hertz}$	$\frac{1}{\text{sec}} = \text{hertz}$

Sometimes we will measure energy in electron-Volts:

$$1\ \text{eV} = 1.602 \times 10^{-19}\ \text{Joules}$$

Math Skills

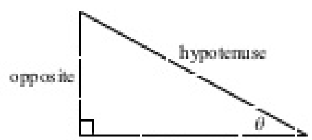
- We will make use of the following concepts:
  - Algebra
    - One equation in one unknown
    - Sine, cosine, tangent, exponentials
  - Basic geometry
    - Right triangles, Pythagoras' theorem
  - Scientific notation
    - Including SI prefixes (kilo, mega, micro, etc…)
  - Simple vector concepts
- If you are uncomfortable with any of these, please do something!

Math Skills

Trig Cheat Sheet

Definition of the Trig Functions

Right triangle definition
For this definition we assume that $0 < \theta < \frac{\pi}{2}$ or $0^\circ < \theta < 90^\circ$.

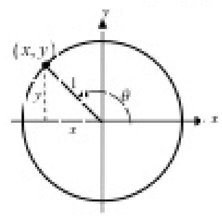


$\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}}$ $\csc\theta = \frac{\text{hypotenuse}}{\text{opposite}}$

$\cos\theta = \frac{\text{adjacent}}{\text{hypotenuse}}$ $\sec\theta = \frac{\text{hypotenuse}}{\text{adjacent}}$

$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$ $\cot\theta = \frac{\text{adjacent}}{\text{opposite}}$

Unit circle definition
For this definition θ is any angle.



$\sin\theta = \frac{y}{1} = y$ $\csc\theta = \frac{1}{y}$

$\cos\theta = \frac{x}{1} = x$ $\sec\theta = \frac{1}{x}$

$\tan\theta = \frac{y}{x}$ $\cot\theta = \frac{x}{y}$

Facts and Properties

Domain
The domain is all the values of θ that can be plugged into the function.

$\sin\theta$, θ can be any angle
$\cos\theta$, θ can be any angle
$\tan\theta$, $\theta \neq \left(n+\frac{1}{2}\right)\pi$, $n = 0, \pm1, \pm2, \ldots$
$\csc\theta$, $\theta \neq n\pi$, $n = 0, \pm1, \pm2, \ldots$
$\sec\theta$, $\theta \neq \left(n+\frac{1}{2}\right)\pi$, $n = 0, \pm1, \pm2, \ldots$
$\cot\theta$, $\theta \neq n\pi$, $n = 0, \pm1, \pm2, \ldots$

Range
The range is all possible values to get out of the function.

$-1 \le \sin\theta \le 1$ $\csc\theta \ge 1$ and $\csc\theta \le -1$
$-1 \le \cos\theta \le 1$ $\sec\theta \ge 1$ and $\sec\theta \le -1$
$-\infty < \tan\theta < \infty$ $-\infty < \cot\theta < \infty$

Period
The period of a function is the number, T, such that $f(\theta + T) = f(\theta)$. So, if ω is a fixed number and θ is any angle we have the following periods.

$\sin(\omega\theta) \rightarrow T = \frac{2\pi}{\omega}$
$\cos(\omega\theta) \rightarrow T = \frac{2\pi}{\omega}$
$\tan(\omega\theta) \rightarrow T = \frac{\pi}{\omega}$
$\csc(\omega\theta) \rightarrow T = \frac{2\pi}{\omega}$
$\sec(\omega\theta) \rightarrow T = \frac{2\pi}{\omega}$
$\cot(\omega\theta) \rightarrow T = \frac{\pi}{\omega}$

Formulas and Identities

Tangent and Cotangent Identities
$\tan\theta = \frac{\sin\theta}{\cos\theta}$ $\cot\theta = \frac{\cos\theta}{\sin\theta}$

Reciprocal Identities
$\csc\theta = \frac{1}{\sin\theta}$ $\sin\theta = \frac{1}{\csc\theta}$
$\sec\theta = \frac{1}{\cos\theta}$ $\cos\theta = \frac{1}{\sec\theta}$
$\cot\theta = \frac{1}{\tan\theta}$ $\tan\theta = \frac{1}{\cot\theta}$

Pythagorean Identities
$\sin^2\theta + \cos^2\theta = 1$
$\tan^2\theta + 1 = \sec^2\theta$
$1 + \cot^2\theta = \csc^2\theta$

Even/Odd Formulas
$\sin(-\theta) = -\sin\theta$ $\csc(-\theta) = -\csc\theta$
$\cos(-\theta) = \cos\theta$ $\sec(-\theta) = \sec\theta$
$\tan(-\theta) = -\tan\theta$ $\cot(-\theta) = -\cot\theta$

Periodic Formulas
If n is an integer.
$\sin(\theta + 2\pi n) = \sin\theta$ $\csc(\theta + 2\pi n) = \csc\theta$
$\cos(\theta + 2\pi n) = \cos\theta$ $\sec(\theta + 2\pi n) = \sec\theta$
$\tan(\theta + \pi n) = \tan\theta$ $\cot(\theta + \pi n) = \cot\theta$

Double Angle Formulas
$\sin(2\theta) = 2\sin\theta\cos\theta$
$\cos(2\theta) = \cos^2\theta - \sin^2\theta$
$= 2\cos^2\theta - 1$
$= 1 - 2\sin^2\theta$
$\tan(2\theta) = \frac{2\tan\theta}{1-\tan^2\theta}$

Degrees to Radians Formulas
If x is an angle in degrees and t is an angle in radians then
$\frac{\pi}{180} = \frac{t}{x} \Rightarrow t = \frac{\pi x}{180}$ and $x = \frac{180t}{\pi}$

Half Angle Formulas
$\sin^2\theta = \frac{1}{2}(1 - \cos(2\theta))$
$\cos^2\theta = \frac{1}{2}(1 + \cos(2\theta))$
$\tan^2\theta = \frac{1-\cos(2\theta)}{1+\cos(2\theta)}$

Sum and Difference Formulas
$\sin(\alpha \pm \beta) = \sin\alpha\cos\beta \pm \cos\alpha\sin\beta$
$\cos(\alpha \pm \beta) = \cos\alpha\cos\beta \mp \sin\alpha\sin\beta$
$\tan(\alpha \pm \beta) = \frac{\tan\alpha \pm \tan\beta}{1 \mp \tan\alpha\tan\beta}$

Product to Sum Formulas
$\sin\alpha\sin\beta = \frac{1}{2}\left[\cos(\alpha-\beta) - \cos(\alpha+\beta)\right]$
$\cos\alpha\cos\beta = \frac{1}{2}\left[\cos(\alpha-\beta) + \cos(\alpha+\beta)\right]$
$\sin\alpha\cos\beta = \frac{1}{2}\left[\sin(\alpha+\beta) + \sin(\alpha-\beta)\right]$
$\cos\alpha\sin\beta = \frac{1}{2}\left[\sin(\alpha+\beta) - \sin(\alpha-\beta)\right]$

Sum to Product Formulas
$\sin\alpha + \sin\beta = 2\sin\left(\frac{\alpha+\beta}{2}\right)\cos\left(\frac{\alpha-\beta}{2}\right)$
$\sin\alpha - \sin\beta = 2\cos\left(\frac{\alpha+\beta}{2}\right)\sin\left(\frac{\alpha-\beta}{2}\right)$
$\cos\alpha + \cos\beta = 2\cos\left(\frac{\alpha+\beta}{2}\right)\cos\left(\frac{\alpha-\beta}{2}\right)$
$\cos\alpha - \cos\beta = -2\sin\left(\frac{\alpha+\beta}{2}\right)\sin\left(\frac{\alpha-\beta}{2}\right)$

Cofunction Formulas
$\sin\left(\frac{\pi}{2}-\theta\right) = \cos\theta$ $\cos\left(\frac{\pi}{2}-\theta\right) = \sin\theta$
$\csc\left(\frac{\pi}{2}-\theta\right) = \sec\theta$ $\sec\left(\frac{\pi}{2}-\theta\right) = \csc\theta$
$\tan\left(\frac{\pi}{2}-\theta\right) = \cot\theta$ $\cot\left(\frac{\pi}{2}-\theta\right) = \tan\theta$

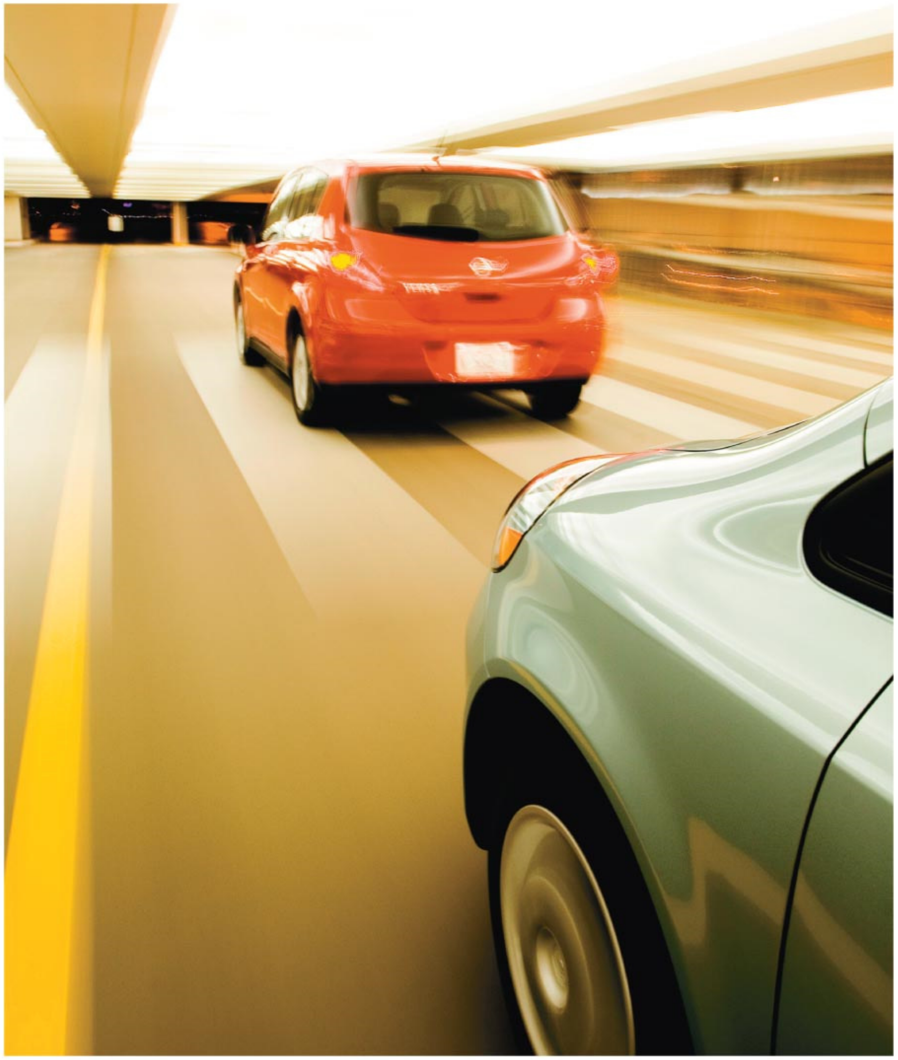
Math Skills

Prefixes	Value	Standard form	Symbol
Tera	1 000 000 000 000	10^{12}	T
Giga	1 000 000 000	10^{9}	G
Mega	1 000 000	10^{6}	M
Kilo	1 000	10^{3}	k
deci	0.1	10^{-1}	d
centi	0.01	10^{-2}	c
milli	0.001	10^{-3}	m
micro	0.000 001	10^{-6}	μ
nano	0.000 000 001	10^{-9}	n
pico	0.000 000 000 001	10^{-12}	p

Chapter 1

- Kinematics is the study of how objects move
- Chapter 1 introduces various ways to describe “motion”
- Terms like “velocity” and “acceleration” have very precise definitions
- Your physical intuition is probably already pretty good so that’s where we will start…

Objects in Motion



- A person watching cars drive by would say that they were moving.
- They might also say that everything inside those cars is also moving.
- Including a coffee cup…

Objects in Motion

- A person riding in a car might say that the coffee cup is at rest… it's not moving.
- Which person is right? Or are they both right?

Objects in Motion

- You need to identify both the ***object of interest*** AND the ***observer*** to describe the motion of the object.
- The coffee cup is moving when the observer is standing on the sidewalk.
- The coffee cup is not moving when the observer is riding in the car.
- This confused people for hundreds of years.

What is Motion?

- Motion is the *change* in an object's position *relative to a given observer* during a certain time interval.
- Without identifying the observer, you can't say whether the object moved.
- A reference frame provides:
  - An object (or a point on an object) of reference
  - A coordinate system with a scale for measuring distance
  - A clock for measuring time

Linear Motion

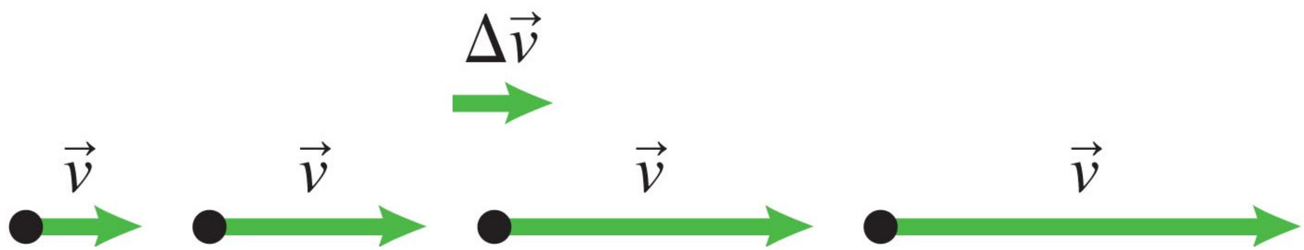
- For now we will treat objects as points that move in a straight line
  - If the object is large, just pick a point on the object
  - This usually won't work if the object is rotating, so in all the examples it won't be.
- We assume we can choose a reference frame and tell where the (point on the) object is at any time.
- We can describe it's motion in several ways…

Motion Diagrams

- Dots represent the location of the object at different, equally spaced time intervals.
  - All distances are measured relative to the origin in the observer's reference frame
- The speed of the object at each point is represented by an arrow, $\vec{v}$.
  - The length of the arrow indicates how fast the object is moving
- We can also draw how the speed changes in each time interval, $\Delta\vec{v}$.

Motion Diagrams

When the velocity change is constant from time interval to time interval, we need only one $\Delta\vec{v}$ for the diagram.



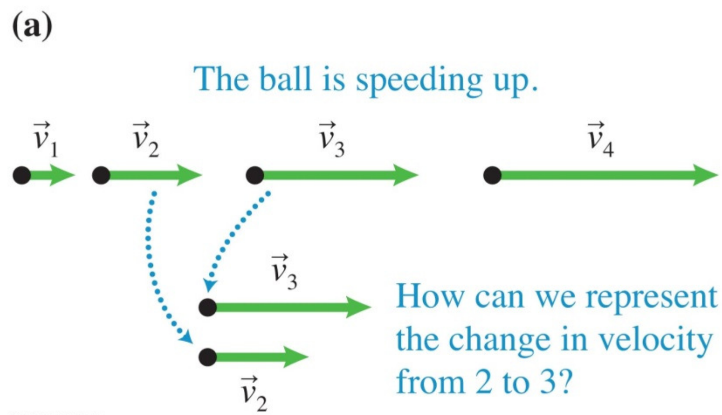
- Dots get farther apart when the object speeds up
- Dots get closer together when the object slows down.
- Dots are equally spaced when the speed is constant.

“Change in Velocity” Arrows

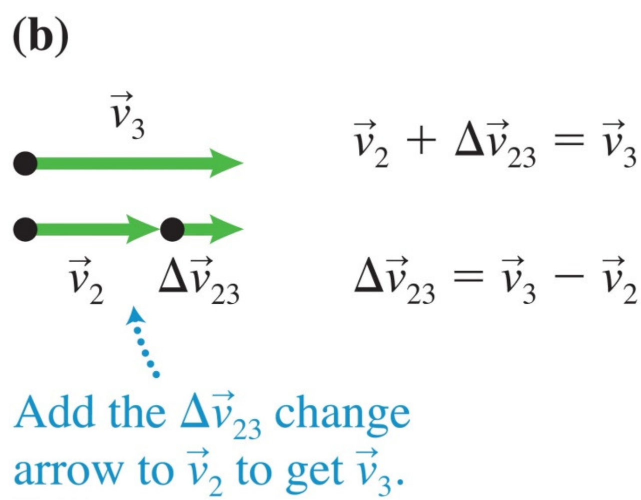
- The notation “Δ” (ie, capital delta) means “change in”.
- We always define “change” as “final” minus “initial”.
- A change in some quantity can be positive or negative. It has both **magnitude** and **direction**.
- The arrow above the $\vec{v}$ reminds us that it has both magnitude and direction.

Finding Velocity Change Arrows

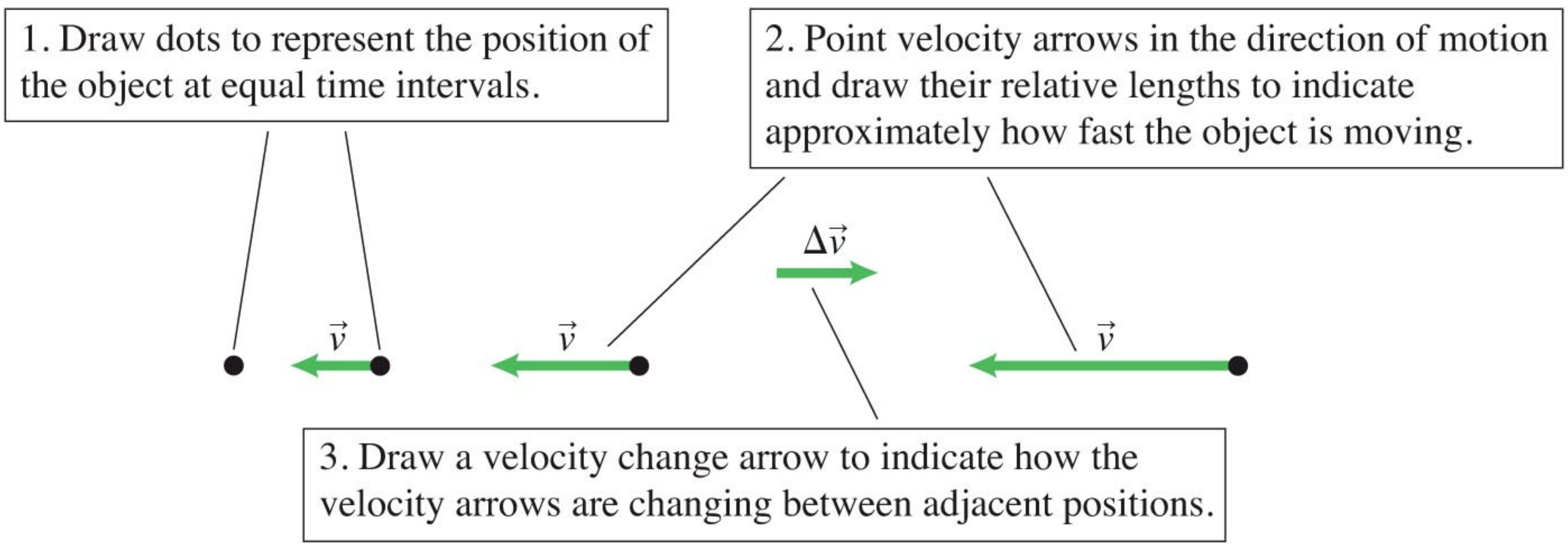
- Consider two adjacent velocity vectors, in this example at points 2 and 3.



- Find which vector would need to be added to the velocity corresponding to point 2 to get the velocity corresponding to point 3.



Constructing a Motion Diagram



Quantities Describing Motion

- Motion diagrams represent motion qualitatively.
- To describe motion precisely, we need a more quantitative representation.
- To describe linear motion, we need to define:
  - Time and time interval
  - Position, displacement, distance, and path length
  - Scalar components of displacement for motion along one axis

Time and Time Interval

- The time t is a clock reading.
- The time interval $(t_2 - t_1)$ or Δt is a difference in clock readings.
  - The symbol delta represents "change in" and is the ***final value*** minus the ***initial value***.
- These are both scalar quantities.
- The SI units for both quantities are seconds (s).

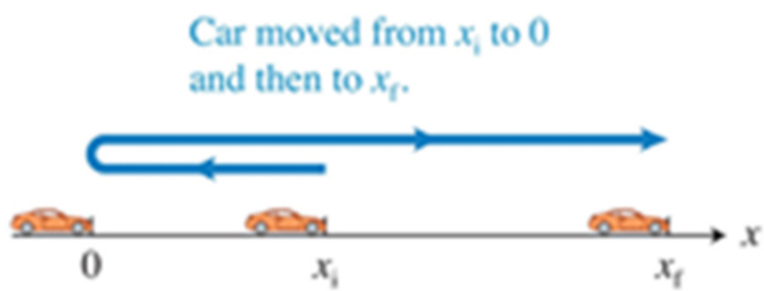
Position, displacement, etc…

- **Position** is an object's location with respect to a particular coordinate system.
- **Displacement** is a vector that starts from an object's initial position and ends at its final position.
- **Distance** is the magnitude (length) of the displacement vector.
- **Path length** is how far the object moved as it traveled from its initial position to its final position.
  - Imagine laying a string along the path the object took. The length of the string is the path length.

Example: A car backs up (moving in the negative direction) toward the origin of the coordinate system at $x = 0$. The car stops and then moves in the positive x-direction to its final position x_f.

- The initial position and the origin of a coordinate system are not necessarily the same points.
- The displacement for the whole trip is a vector that points from the starting position at x_i to the final position at x_f.
- The distance for the trip is the magnitude of the displacement (always positive).
- The path length is the distance from x_i to 0 plus the distance from 0 to x_f. Note that the path length does not equal the distance.

(c) Path length l



$$l = |x_i - 0| + |x_f - 0|$$